Quantum control of two qubits spin hole gates

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Hole spins in semiconductor quantum dots (QDs) are attracting significant attention as candidates for fast, highly coherent, spin qubits [1-4]. They have long coherence time due to the weak hyperfine coupling to nuclear spins and have demonstrated to have rapid operation times due to the inherently strong spin–orbit coupling (SOC).

In this work we investigate how to control a two-hole spin qubit consisting of a triplet and a singlet hole states. For that purpose, we implement a driving protocol based on Shortcuts to Adiabaticity (STA), minimizing noise effects while enhancing robustness [5, 6]. We consider the fast quasi-adiabatic (FAQUAD) approach and analyze its feasibility to manipulate hole spin qubits and compare with other alternative protocols. We can initialize the qubit in an arbitrary state and perform a NOT gate by changing the detuning between dots. In addition, we achieve a SWAP-like two-qubits gate with a fidelity beyond error correction threshold. We study the robustness of the protocol regarding systematic errors in the detuning, as well as charge noise [7].

Furthermore, we study the direct transfer of entangled holes in QD arrays between edge sites by using inverse engineering techniques. We demonstrate that spin-conserving and spin-flipping direct transfer between edges can be achieved in a controlled way with all-electrical protocols by dynamically tuning the tunnelling rates between dots [8].

References

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Figures

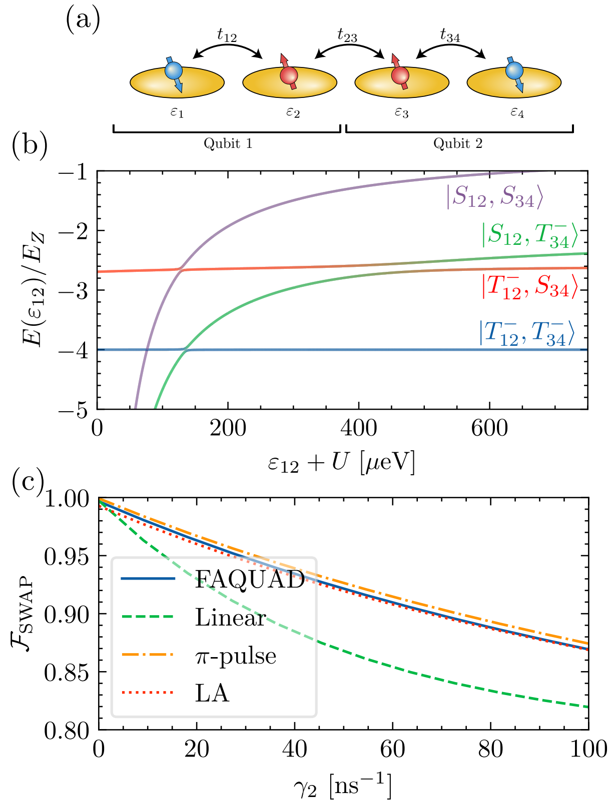

Figure 1: (a) Schematic picture of a quadruple quantum dot encoding two S-T qubits. (b) Energy level diagram of the system. (c) Fidelity of a SWAP gate against charge noise for different protocols.